EXPLORING COIL MEASUREMENTS

Contents

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers, contractors and other interested parties with technical information for using an exploring coil during noise investigations. Noise investigations may be undertaken where telephone plant is operational, non operational or along proposed routes.

1.2 An exploring coil can be used to locate and identify various power line components that may be contributing to a telephone system noise problem. An exploring coil is also used to measure the overall or

or individual harmonic frequency earth return current of a power line. (See TE&CM Section 452, Paragraph 9.2.)

1.3 An exploring coil is small and lightweight and thus easy to transport. Little time is required at a site to prepare for measurement making it more convenient than a probe wire. (See TE&CM Section 452.3).

1.4 Earth return current is usually measured along a power line after it has been determined that circuit noise in a telephone system cannot be reduced to an acceptable level through further work on the telephone plant. In other words, cable balance is excellent, cable shield continuity has been verified by measurement and the source of the noise is through induction and not within the telephone system. Another situation where the measurement of power system earth return current might be desirable is where a new cable extension is planned parallel to an existing power line. The expected power influence can be calculated from the average earth return current as determined from measurements of earth return current along the proposed route. Thus if a neutralizing transformer is required it can be included in the transmission design or the proposed routing changed.

1.5 The technique for measuring power line earth return currents is effective on single-, two-, or three phase systems. In general, the technique can be used to measure the earth return current associated with any conductor or group of conductors. This also applies to buried telephone cable.

2. EXPLORING COIL SURVEY OF POWER SYSTEM

2.1 An exploring coil in conjunction with a spectrum analyzer can be used for rapid diagnosis of power line operating conditions which may be contributing to a telephone noise problem. This is especially true when an analysis of the power influence on a telephone cable pair as discussed in TE&CM Section 452.1 has identified the predominant harmonic frequency. This frequency will often be 540 Hertz, the ninth harmonic of the fundamental (60 Hertz) power line frequency. When an analysis of the power influence on a cable pair has not been completed this diagnostic tool can still be utilized. Since the ninth harmonic is the predominant interfering frequency in the majority of noise investigations this harmonic may be used for studying the power line where the actual predominant interfering frequency has not been determined.

2.2 Connect the exploring coil to the input of the spectrum analyzer. Set the spectrum analyzer for bridged measurement and to the harmonic frequency of interest. Where the test set has automatic frequency control (AFC) it should be used to compensate for drift. Hold the coil outside the vehicle window and point it directly at the power wires as shown in Figure 1. The coil should be oriented to obtain maximum reading on the analyzer. Some investigators also monitor the audible noise with earphones when a monitor jack is available on the test set.

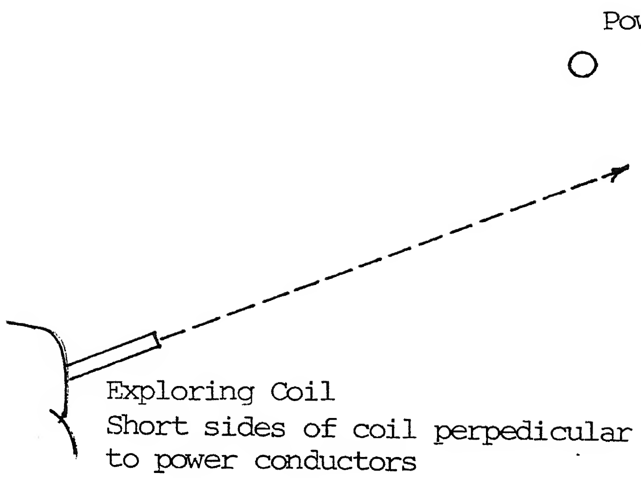


FIGURE 1
POWER SYSTEM SURVEY

2.2.1 Move along the power line in the vehicle observing the magnitude of the harmonic frequency. As the location of the power line changes in relation to the road it will be necessary to reorient the exploring coil to obtain the maximum reading on the analyzer. The entire power line should be studied even though it extends beyond the telephone system. The factor(s) in the power system contributing to telephone interference need not be located in spans where the systems are parallel.

2.2.2 When a point is passed where there is a significant change in the magnitude of the harmonic frequency, return to the point and determine why. Such a change might occur at a capacitor bank location which due to a resonant power line condition is providing a low impedance path to earth for that particular harmonic frequency current. A reduction in magnitude might occur where a tap leaves the main power line and the current is flowing in the tap.

2.2.3 When the reduction occurs at a tap location the tap should be studied in the same manner discussed above until the factor(s) contributing to the noise have been identified. Then the study of the main power line route can be completed.

2.3 After possible contributors to the telephone interference have been identified measurements of the power line earth return current should be completed on both sides of the locations to verify its contribution. The measurement of earth return current with an exploring coil is discussed in Paragraph 3 and with a probe wire in TE&CM Section 452.3.

3. MEASUREMENT OF EARTH RETURN CURRENT

3.1 Selection of a location for measurement of power line earth return currents is an important consideration. It must be free as possible from factors that might produce erroneous results. Things to avoid are:

3.1.1 Power line spans that include secondary distribution conductors should be avoided. The presence of secondary distribution conductors alters the magnetic field and can cause significant errors in earth return current measurements.

3.1.2 Discontinuities in the power line such as bridged taps, distribution transformers, corners or dead-ends should also be avoided. These will distort the magnetic field from the power line and cause errors in the earth return current measurements.

3.1.3 Metal fences located beneath or near a power line and parallel to it should be avoided. The magnetic field from a grounded metal fence may be stronger at the earth's surface than that from the power line. This could result in a large error in earth return current measurements.

3.1.4 Sections where power and telephone lines share poles should also be avoided unless the joint use extends through the entire exposure. Recorded results of measured earth return current where the entire exposure is in joint-use are not the true values. The error is due to the cable's location near the power conductor. Variations in earth return current along the power line and the predominat harmonics of the fundamental frequency can still be determined.

3.1.5 The exploring coil should not be used where a buried cable or metallic pipe line is located beneath or very near the power line. The magnetic field from either of these may be stronger than that from the power line at the earth's surface. This will produce erroneous results.

3.2 The site selected should be at the center of a span to obtain the highest reading on the meter. After a site has been selected for ...ments determine the distance from the center of the exploring ... neutral and each phase conductor. Where the distance is estimated ...ust be within ± two (2) feet. The exploring coil is more sensitive ...anges in distance to the powerline than a probe wire (See TE&CM 452.3). If available the use of a rangefinder is recommended for ...ing this distance.

...te the average distance to the power conductors from the ... of the exploring coil. This will be the average distance to ...ctors (one neutral and three phase conductors) on a three-... . It will be the average of two conductors (one neutral and ...on a single-phase line.

...e average distance in the appropriate space (1) on the form ...er system current wave form analysis. A sample form is ... . The sample form is designed for use when measuring with ...ng coil or probe wire.

POWER SYSTEM CURRENT WAVE FORM ANALYSIS

Central Office ____________________

Power Company ____________________ Sheet No. ____________________

Primary Voltage ____________________ Date ____________________

Test Location ____________________ Time ____________________

Test Condition ____________________ Tester ____________________

☐ 100 foot probe wire ____________________ ☐ Exploring coil type: ____________________

Power Line Height (Average) __________ Feet (1); Correction Factor ____________________ dB (2)

FREQ. Hz.	Harmonic	TIF Weighted (Weighing Switch in C-MSG.)			Unweighted (Weighing Switch in 50 KHZ-FLAT or 20/F)					TIF Contribution	
		Reading dB (3)	(2)+(3) $I_f \cdot W_f$ dBA (4)	$I_f \cdot W_f$ wtd. amps (5)	Flat Reading dB (6)	20/f Factor (7)	(6)+(7) or 20f Reading (8)	(8)+(2) -40 dB =(I_f)dBA (9)	I_f amps (10)	(3)-(8) +40 dB =(T_f) dB (11)	T_f (12)
60	1					-9.5					
120	2					-15.6					
180	3					-19.1					
240	4					-21.6					
300	5					-23.5					
360	6					-25.1					
420	7					-26.4					
480	8					-27.6					
540	9					-28.6					
600	10					-29.5					
660	11					-30.4					
720	12					-31.1					
780	13					-31.8					
840	14					-32.5					
900	15					-33.1					
960	16					-33.6					
1020	17					-34.2					
1140	19					-35.1					
1260	21					-36.0					
1380	23					-36.8					
1500	25					-37.5					
1620	27					-38.2					
1740	29					-38.8					
1860	31					-39.4					
1980	33					-40.0					
2100	35					-40.4					
2220	37					-40.9					
2340	39					-41.4					
2460	41					-41.8					
2580	43					-42.2					
2700	45					-42.[illegible]					
2820	47					-43.[illegible]					
2940	49					-43.3					
3060	51					-43.7					
3180	53					-44.0					
			(I·T)dB	I·T				(I) dBA	I	(TIF)dB	TIF
PWR SUM											
NMS											

		Height of Power Line Above Probe Wire or Coil								
		20'	25'	30'	35'	40'	45'	50'	55'	60'
Height Correction Factor dB	100' Probe Wire	0.5	1.1	1.6	2.1	2.5	2.9	3.3	3.6	3.9
	Exploring Coil	19.5	21.5	23.0	24.4	25.5	26.6	27.5	28.3	29.1

FIGURE 2

3.2.3 Find the correction factor in the table at the bottom of the form for the average power line height (average distance from center of coil to power conductors) and enter it in the appropriate space (2). The correction factors are based on the dimensions of the Wilcom Products, Inc. CCS-105 exploring coil since, at the time of this writing, it is the only one known to be on the market. This does not constitute an endorsement of this product by REA or imply other exploring coils of equal or other dimensions which might be available cannot be used to measure earth return current. With coils of different area it is necessary to compute new correction factors as discussed in TE&CM Section 452, Paragraph 9.

3.3 Connect the exploring coil to the spectrum analyzer with a two-wire cord having a dual banana plug at each end. Position the exploring coil directly under the power conductors so that the short sides of the coil are perpendicular to the lines and the long sides parallel as shown in Figure 3.

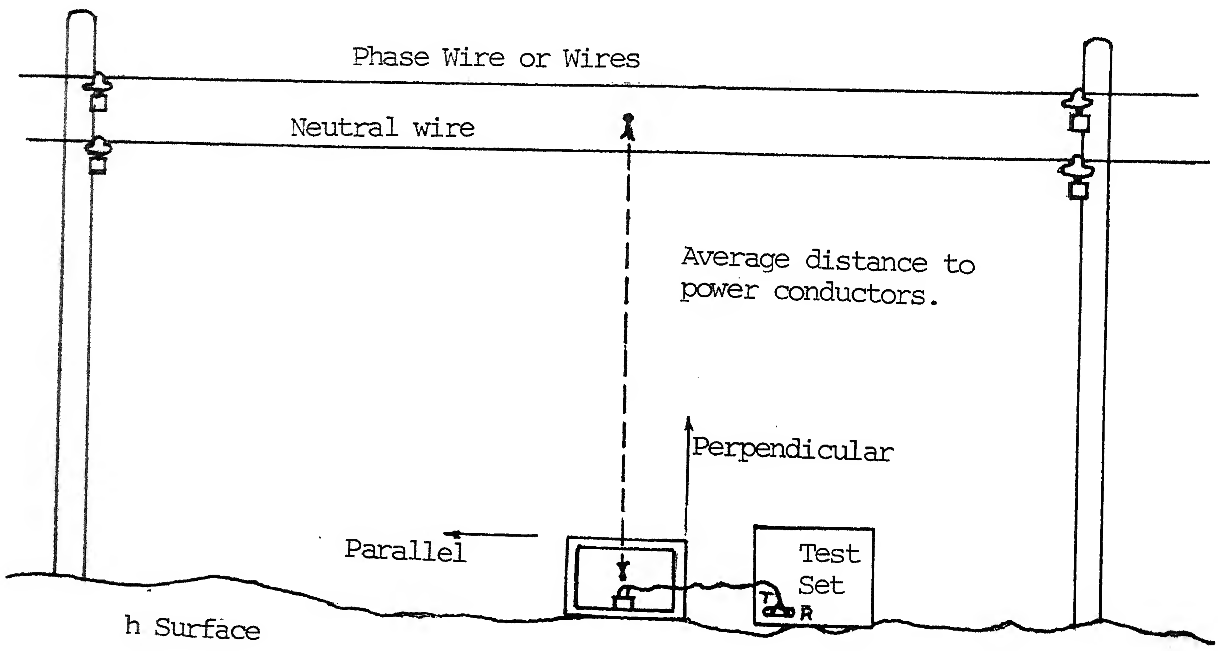


FIGURE 3
MEASUREMENT OF EARTH RETURN CURRENT

3.3.1 When using a spectrum analyzer designed for telephone system measurements set the function switch to the BRDG 600 positon. Place the weighting switch to the desired weighting (C-MSG, 50 kHz FLAT or 20/f), if available.

3.3.1.1 A 50 kHz FLAT weighting filter may not be available on all test equipment. A 3 kHz FLAT weighting should not be used for these measurements since it may be necessary to measure frequencies higher than

the filter cut off frequency. Any higher weighting provided such as 8 kHz FLAT or 15 kHz Flat would be adequate.

3.3.1.2 Not all available test equipment has a 20/f weighted filter. Further, accurate readings with this weighting can only be made at harmonics of the fundamental frequency with a measured valued one tenth ampere or higher earth return current. For example, a reading of 0 dBrn at a point with an average power line height of 20 feet indicates an earth return current of 0.09 ampere. Where long exposures are involved, it is desirable to identify earth return currents of 0.05 ampere. This is a meter reading of -5.5 dBrn. Since with most spectrum analyzers accurate readings cannot be made below 0 dBrn weighting factors in dBrn for 20/f have been included in column (7) of the sample form shown in Figure 2. 20/f weighted values are derived by adding these values to the recorded flat readings. The factors are also used when the available test equipment does not have a 20/f weighted filter.

3.3.2 Set the spectrum analyzer to the desired frequency. Rock the exploring coil slowly from side to side on the longitudinal axis as shown in Figure 4 to the position providing the maximum reading. When the exploring coil and the power line are in the same plane maximum readings of the power line earth return current should be obtained. When the coil at maximum reading is at an angle to the power line plane there is a likelihood it is being influenced by the magnetic field from a buried cable or metallic pipeline.

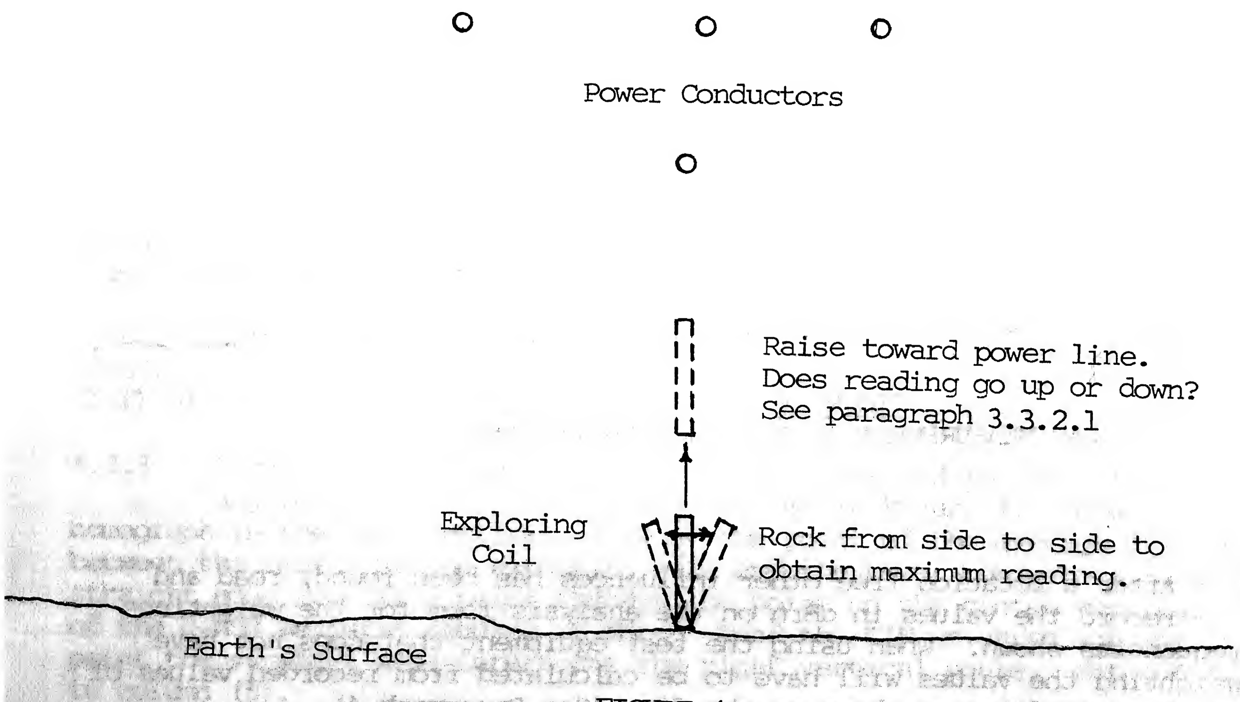


FIGURE 4
PREPARING TO MEASURE EARTH RETURN CURRENT

[illegible] Regardless of previous results lift the coil slowly in the plane of the maximum reading. An increase in the reading indicates the coil is being primarily influenced by the magnetic field from the power line and the measurements may be completed. A decrease in the reading shows the coil is being influenced by the field from a buried cable or metallic pipeline located beneath the power.

[illegible] When a decrease in the reading is found, move the coil thirty feet or more from the power line as shown in Figure 5. Repeat the procedures outlined in Paragraph 3.3.2 and 3.3.2.1 to insure that the coil is being influenced by the magnetic field from the power line. If other influences still mask the power line effects, a new location along the line should be selected for the measurement.

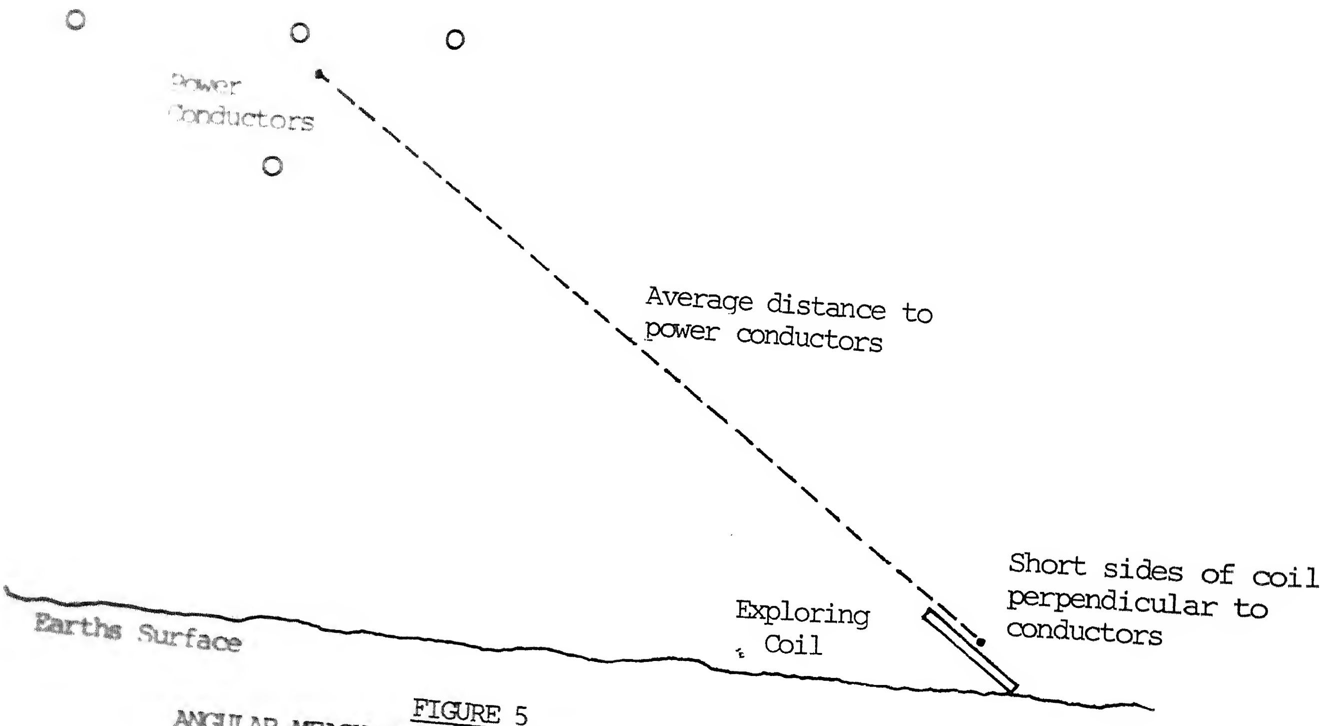


FIGURE 5
ANGULAR MEASUREMENT OF EARTH RETURN CURRENT

3.3.3 After a location free other influences has been found, read and record the values in dBm on the analysis form for the weightings and frequencies shown. When using the test equipment that does not have 20/f weighting the values will have to be calculated from recorded values of flat weighted readings as shown on the form (See Paragraph 4).

3.3.3.1 Switch the operating mode from spectrum analysis to NMS (noise measuring set). Make an overall reading with C-MSG and 20/f weighting. Record the results in the appropriate spaces of the form along the line designated NMS. These overall readings may be converted to numerical overall values of Telephone Interference Factor (TIF), weighted amperes (I·T), and amperes (I) respectively (See TE&CM Section 452) because they are independent of frequency.

3.3.3.2 An overall flat weighted measurement does not have to be made. Flat weighted measurements are frequency dependent and can only be converted to earth return current (I) on a single frequency basis. An overall flat measurement can be used to check the accuracy of the single frequency measurements. This will be discussed in Paragraph 4.

3.3.4 This completes the measurements at a location. Move to the next location that has been selected and repeat the procedures until measurements have been completed at all desired sites.

4. CALCULATION OF EARTH RETURN CURRENT

4.1 There are two methods for converting the recorded results of measurements to numerical values of TIF weighted amperes (I·T) and amperes (I). One is to calculate them as shown on the form for power system current wave form analysis (Figure 2). The other is to determine the values with nomographs designed for the weighting used, C-MSG, FLAT or 20/f.

4.2 The first step is to convert C-MSG weighted readings in column (3) to TIF weighted dB by adding the correction factor at (2) to the reading and enter it in the $I_f \cdot W_f$dBA column (4) of the form (Figure 2). Complete this operation for each frequency and for the overall NMS reading.

4.2.1 Calculate TIF weighted amperes (I·T) by the equation:

$$I \cdot T = \log^{-1}\left(\frac{I_f \cdot W_f \mathrm{dBA}}{20}\right)$$

4.2.2 TIF weighted amperes may also be determined from the curve shown in Figure 6. Enter the bottom horizontal scale at the calculated $I_f \cdot W_f$dBA value from column (4) of the analysis form. Follow the vertical line to the point it intersects the curve. Read the TIF weighted amperes (I·T) of that point on the left vertical scale. Enter value in column (5).

4.2.3 C-MSG weighted readings may also be converted to TIF weighted amperes by use of the nomograph shown in Figure 7. Enter the nomograph in the left vertical scale at the point of the average distance between the center of the exploring coil and the power conductors. Lay a straight edge from this point through the point on the center vertical scale of the C-MSG weighted reading in dBrn. Read the TIF weighted amperes at the point the straight edge intersects the right vertical scale. Enter this value in column (5).

4.2.3.1 There will be combinations of distance and readings where the straight edge will project beyond the limits of the right vertical scale. Where the scale indicates a value over 100 subtract 20 dB from the

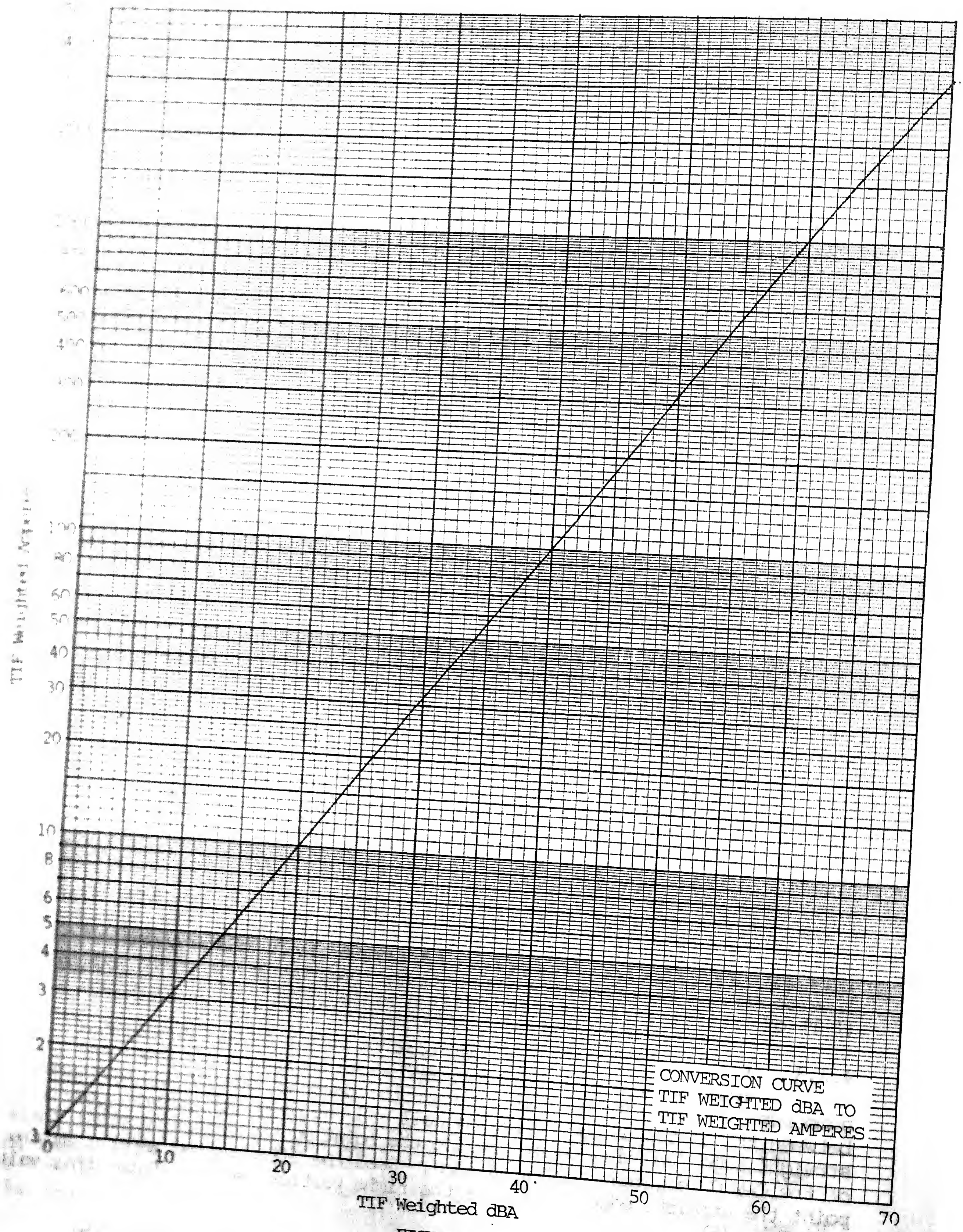
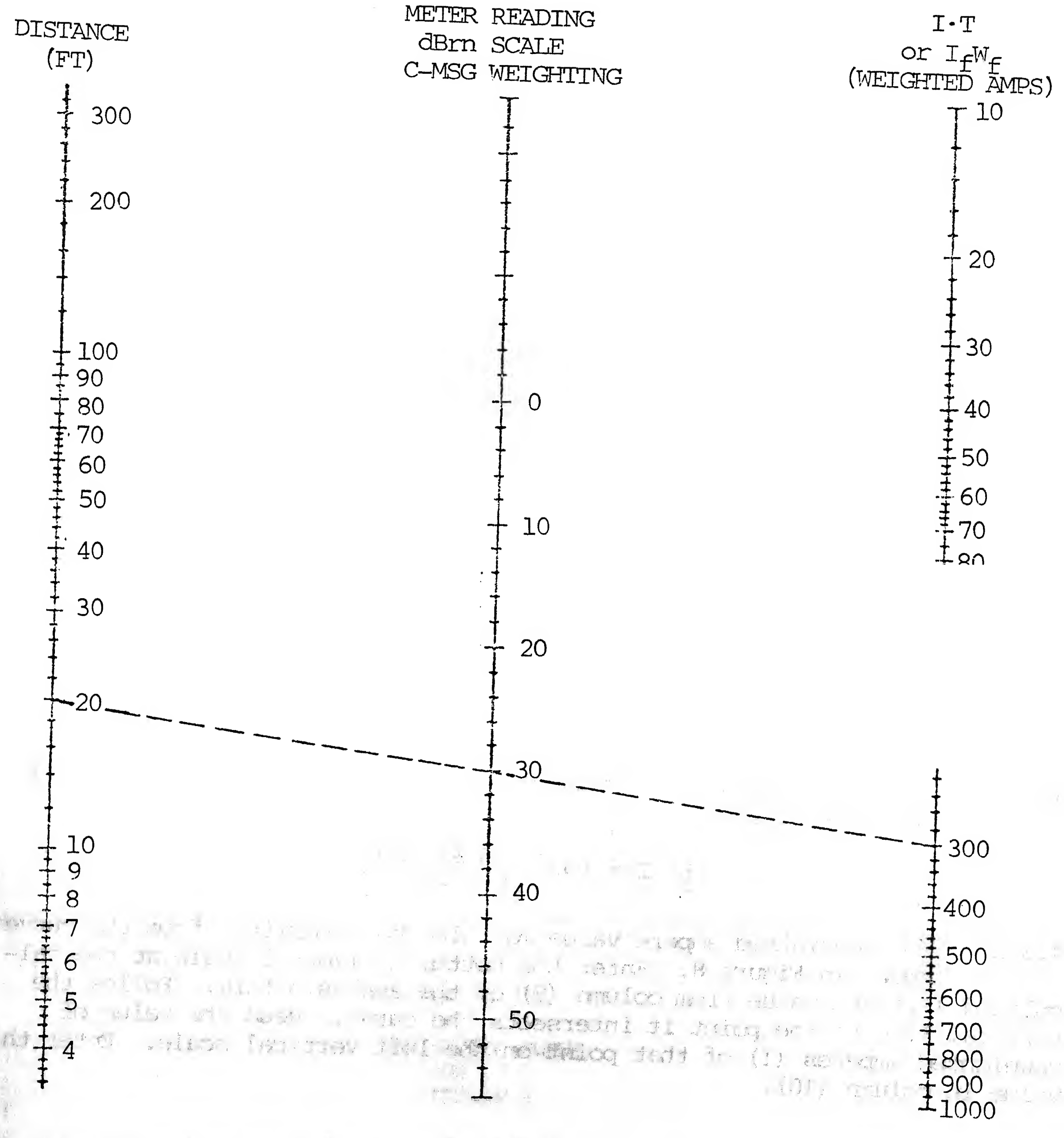

CONVERSION CURVE
TIF WEIGHTED dBA TO
TIF WEIGHTED AMPERES
TIF Weighted dBA
0
10
20
30
40
50
60
70
1
2
3
4
5
6
8
10
20
30
40
50
60
80

FIGURE 6

reading and realign the straight edge. Multiply the I·T value determined in this manner by 10 to obtain the true I·T. As an example, assume a distance of 20 feet and a reading of 50 dBrn. This will be beyond the limits of the right scale. By subtracting 20 dB the straight edge is laid between 20 and 30 giving a reading of 300 on the right scale. Multiplying this by 10 gives 3000 which is the desired I·T.

4.2.3.2 When the value desired is less than 10, add 20 dB to the reading and realign the straight edge. Divide the reading thus obtained by 10 to obtain the desired I·T.



Courtesy of Wilcom Products, Inc.

FIGURE 7

NOMOGRAPH FOR DETERMINING TIF WEIGHTED AMPERES

4.2.4 The operation can be checked by calculating the power summation of columns (3) and (4) and the root sum square (RSS) of column (5). These are both methods for finding the root sum square which is the square root of the sum of the squares of the individual values. Results of power summations are in decibels and of root sum squares in units.

4.2.4.1 The equation for power summation is:

$$\text{PWR SUM} = 10 \log \left(\Sigma \log^{-1} \left(\frac{\text{dB}}{10} \right) \right)$$

4.2.4.2 The equation for root sum square is:

$$\text{RSS} = \sqrt{\Sigma I^2}$$

4.2.5 Calculated values should be nearly equal to the overall measured values in the noise measuring set mode. A large discrepancy indicates an error in either the calculations or in the individual single frequency measurements. This should be found and corrected before proceeding further.

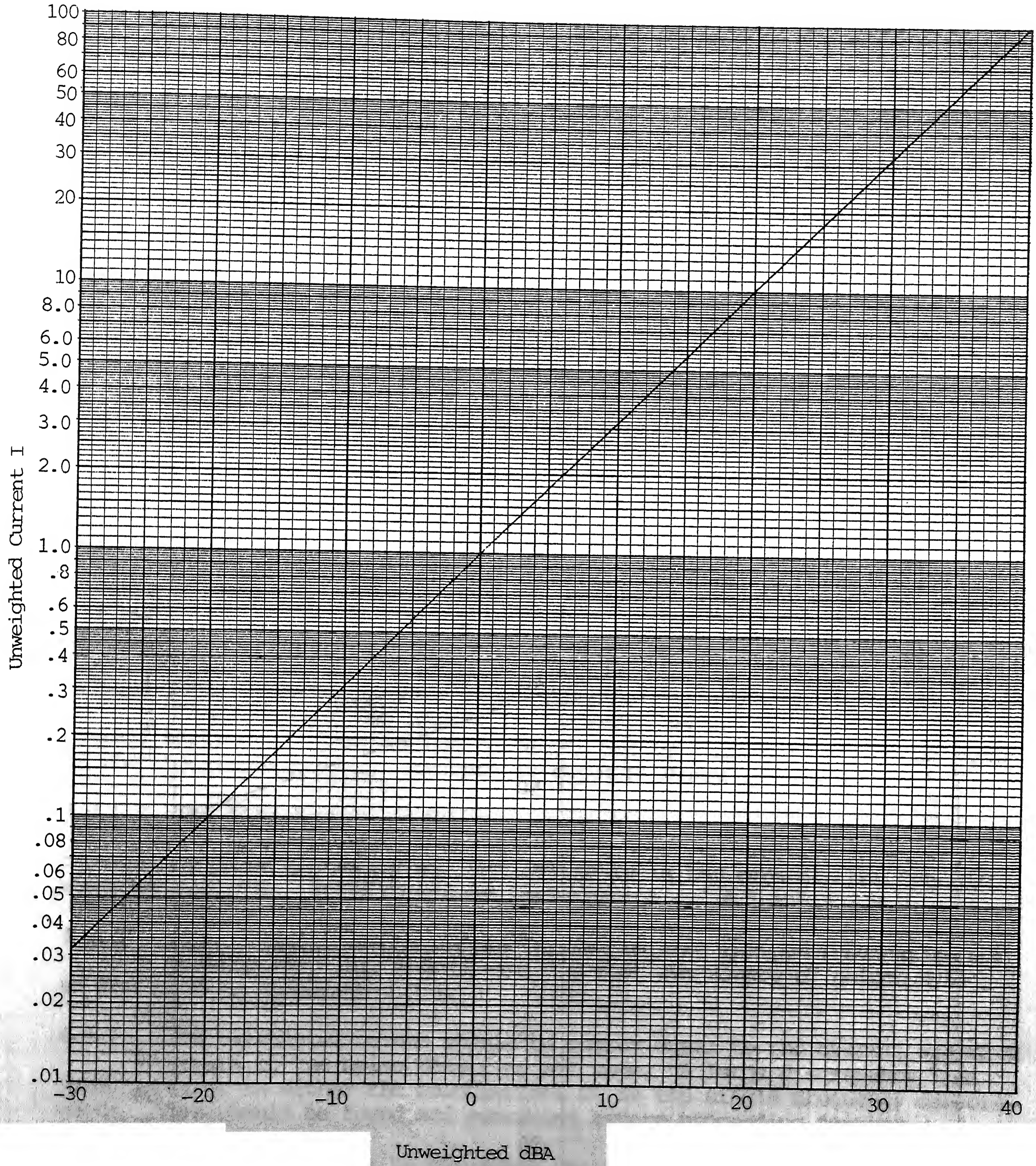
4.3 The next step is to determine the magnitude of the unweighted earth return current. If measurements were made with equipment not having a 20/f filter only the recorded results of flat weighted measurements are available. Convert the results of the flat weighted readings to 20/f values by adding the 20/f weighting factors from column (7) of the analysis form to the recorded flat readings in column (6). Enter the resulting values in column (8). If flat weighted overall readings were taken they cannot be converted to 20/f values since there is no single 20/f factor that can be applied.

4.3.1 When recorded 20/f weighted values are available, either calculated or measured, calculate the unweighted earth return current in (I_f) dBA. Add the correction factor (2) from the analysis form to the recorded 20/f weighted value from the column (8) and subtract 40 from the result. Enter this value of the unweighted current in dBA in column (9). Complete this operation for each frequency and for the overall NMS readings.

4.3.2 The unweighted earth return current in amperes can be calculated from the equation:

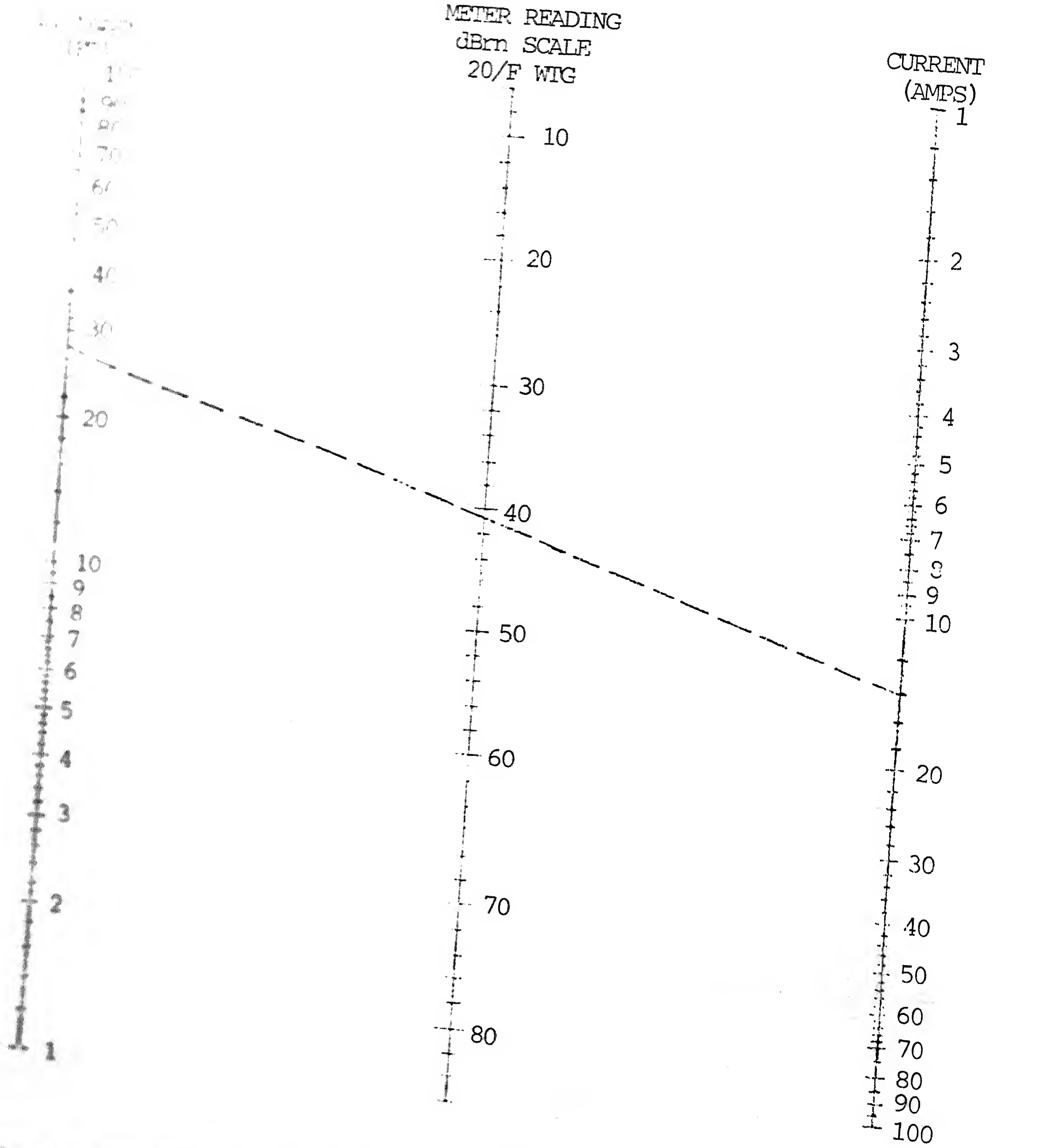
$$I = \log^{-1} \left(\frac{(I_f) \text{ dBA}}{20} \right)$$

4.3.3 The unweighted ampere value may also be determined from the curve shown in Figure 8. Enter the bottom horizontal scale at the calculated (I_f) dBA value from column (9) of the analysis form. Follow the vertical line to the point it intersects the curve. Read the value of unweighted amperes (I) of that point on the left vertical scale. Enter this value in column (10).



CONVERSION CURVE
dBA to I
FIGURE 8

4.14 [illegible] weighted readings can also be converted to unweighted amperes directly by use of the nomograph shown in Figure 9. Enter the nomograph in the left vertical scale at the point of the average distance between the center of the exploring coil and the power conductors. Lay a straight edge from this point through the point on the center vertical scale of the 20/f weighted reading in dBrn. Read the unweighted amperes at the point the straight edge intersects the right vertical scale. Enter this value in column (10).



Courtesy Wilcom Products, Inc. FIGURE 9

NOMOGRAPH FOR DETERMINING EARTH RETURN CURRENT

4.3.4.1 There will be combinations of distance and readings where the straight edge will project beyond the limits of the right vertical scales. Where the scale indicates a value over 100 subtract 20 dB from the reading and realign the straight edge. Multiply the I value thus obtained by 10 to obtain the true current in amperes.

4.3.4.2 When the current value is less than 1 ampere or the 20/f reading is less than 8 dBrnc add 20 dB to the reading and realign the straight edge. If the straight edge intersects the right vertical scale divide the I value by 10 to obtain the current in amperes. When the straight edge indicates a value still less than 1 ampere add 40 dB to the original reading and realign the straight edge. Divide the I value thus obtained by 100 to obtain the current in amperes. As an example assume a distance of 18 feet and a reading of 0 dBrn. When 20 is added to the 0 reading and the straight edge is laid between 18 and 20 it is still off scale. By adding 40 to the 0 reading, the straight edge can be laid between 18 and 40 giving a reading of 8.5 on the right hand vertical scale. Dividing this by 100 gives 0.085 amperes which is usually rounded to 0.1 ampere.

4.3.5 Flat weighted readings can be converted to unweighted amperes directly by use of the nomograph shown in Figure 10. Enter the nomograph in the left vertical scale at the point of average distance between the center of the exploring coil and the power conductors. Lay a straight edge from this point on the center vertical scale of the flat weighted reading in dBrn. Read the value at the point the straight edge intersects the right vertical scale. Divide this value by the order of the harmonic (1, 2, 3, . . .) to obtain the unweighted earth return current.

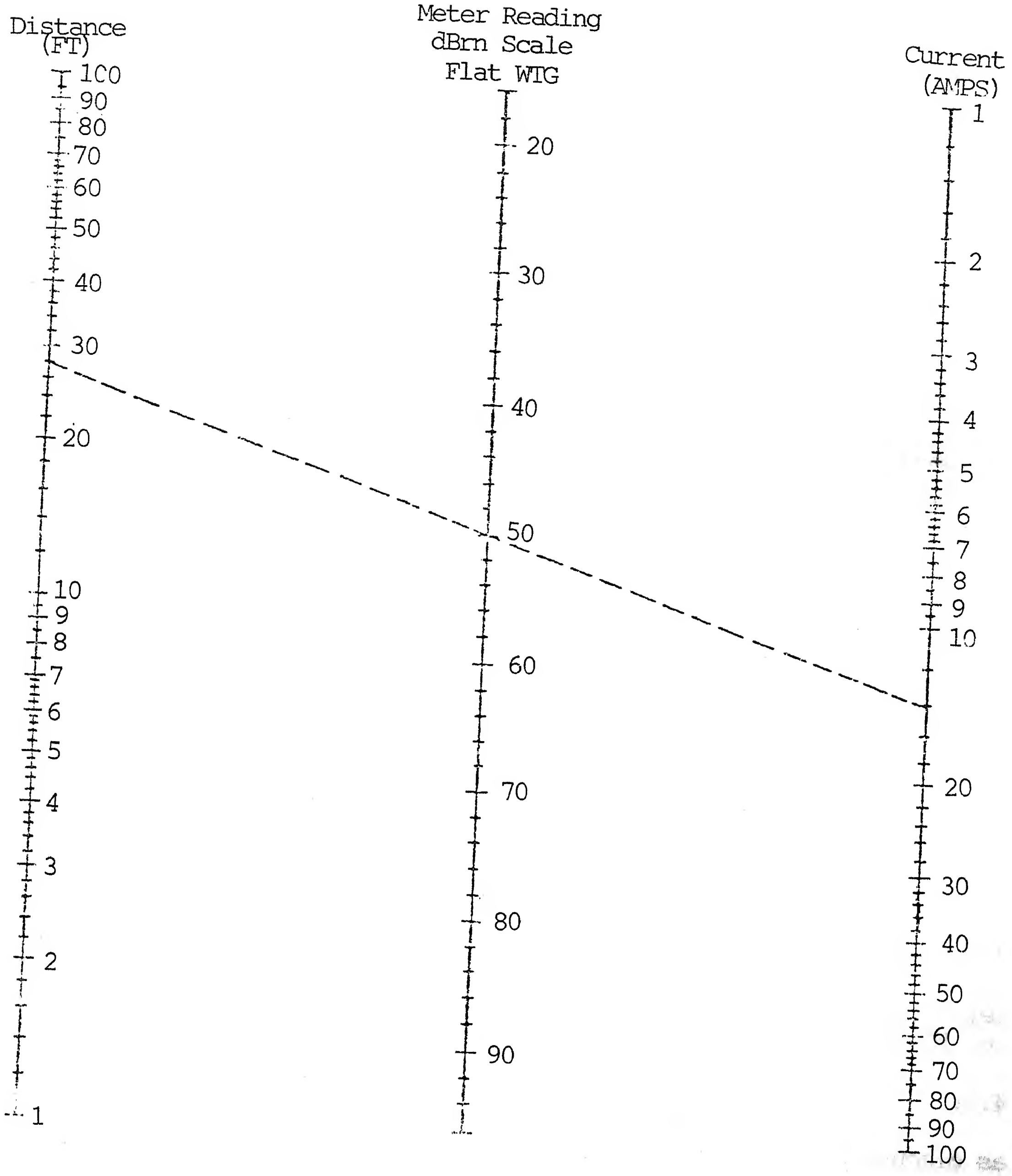
4.3.5.1 Overall earth return current cannot be calculated from an overall flat weighted measurement in the noise measuring set mode. The overall earth return current can be determined by finding the root sum square of the individual harmonic currents as shown in Paragraph 4.2.4.

4.3.5.2 The procedure to be followed where the straight edge extends beyond the limits of the right vertical scale or the reading is above or below those shown on the center vertical scale is the same as that for 20/f weighted readings. It is discussed in Paragraph 4.3.4.1 and 4.3.4.2.

4.3.6 The operation can be checked by determining the power summation of columns (6), (8), and (9) and the root sum square of column (10) as discussed in Paragraph 4.2.4.

4.3.7 The calculated values should be nearly equal to the overall measured values in the noise measuring set mode. A large discrepancy indicates an error in either the calculations or in the single frequency measurements. This should be found and corrected before proceeding further.

4.4 The final step is to calculate the TIF contribution of the earth return current. Subtract the 20/f reading in dBrn in column (8) from the C-MSG reading in column (3) and add 40 to the result. Enter the resulting TIF weighted dB ((T_f) dB) in column (11).



Courtesy Wilcom Products, Inc.

FIGURE 10

NOMOGRAPH FOR DETERMINING EARTH RETURN CURRENT-FLAT WEIGHTED READING

4.4.1 Numerical TIF can be calculated by the equation:

$$\text{Numerical TIF} = \log^{-1}\left(\frac{(T_f)\ dB}{20}\right)$$

4.4.2 The numerical TIF can also be determined from the curve shown in Figure 11. Enter the bottom horizontal scale at the calculated (^{T}f) dB value from column (11) of the analysis form. Follow the vertical line to the point it intersects the curve. Read the TIF value of that point on the left vertical scale. Enter this value in column (12).

4.4.3 Numerical TIF may also be calculated by dividing the TIF weighted amperes from column (5) by the unweighted amperes from column (10).

4.4.4 Calculations should be completed for all individual frequencies and overall measured and calculated values. The TIF values recorded for the harmonic frequencies should agree with the values shown in Table III, Power Harmonic TIF Weighting Factors, TE&CM Section 452.

4.5 An example of a completed form for power system current wave for analysis is shown in Figure 12. It is important that all of the information at the top of the form be provided. The time may indicate the data was obtained during a period of low or high load demand. This can sometimes be valuable during the analysis. Weather conditions can have a direct relation to interference levels.

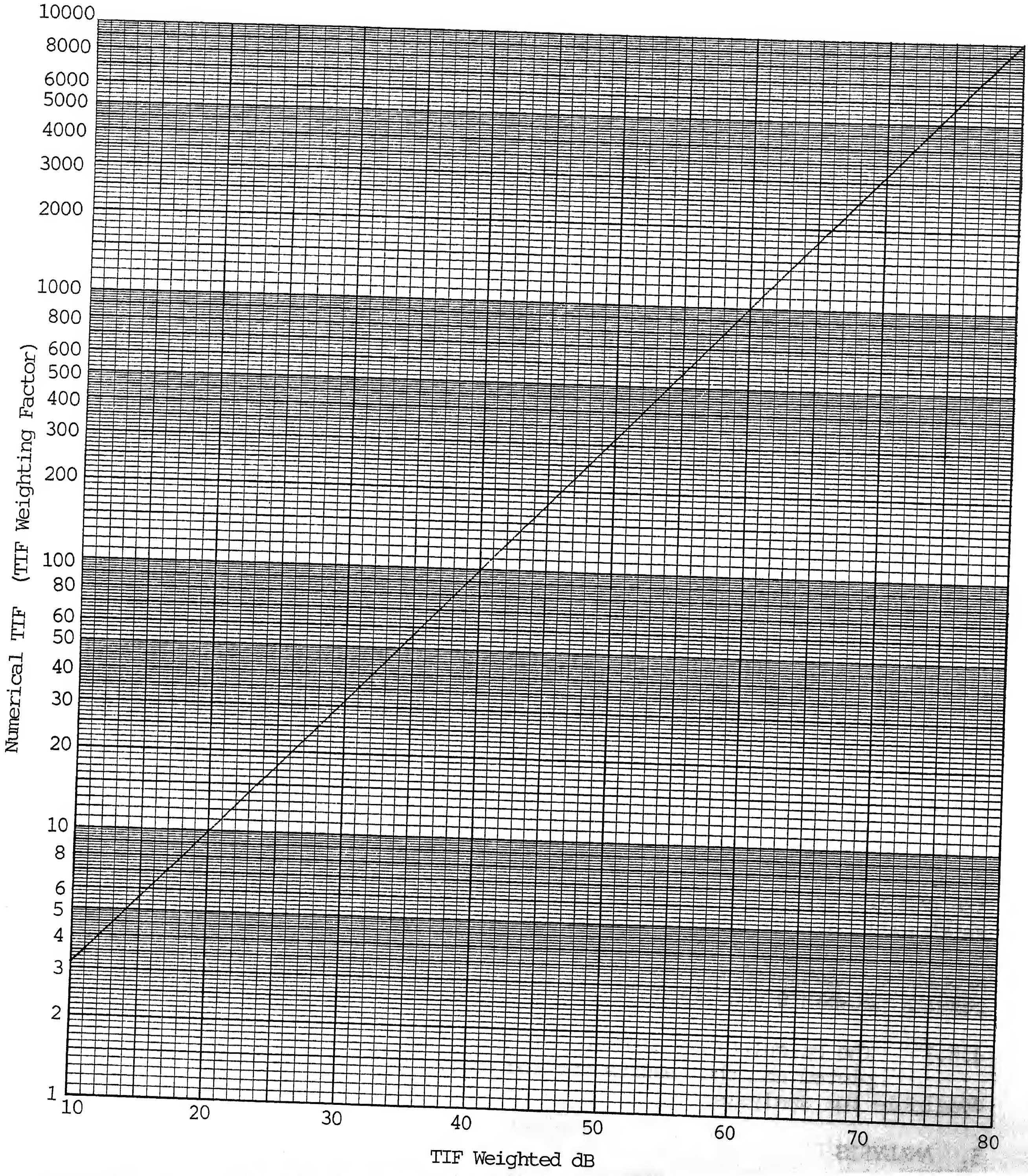
4.5.1 In the example an average distance between the center of the coil and the power conductors of 31 feet will be assumed. Enter this at (1) in the form. Looking at the table of height correction factors for an exploring coil at the bottom of the form a correction factor of 23 dB is found for a 30 foot height. Enter this value at (2) in the form. While a more precise correction factor (23.2 dB) can be found in Figure 16 of TE&CM Section 452 the resulting deviation is small and has no significant effect on the final values obtained.

4.5.2 Complete measurements with C-MSG, FLAT and 20/f weighting and record the results as shown in columns (3), (6), and (8) respectively for the listed frequencies. Complete overall measurements with a NMS and record in the designated spaces. It is not necessary to record readings at the higher harmonic frequencies when it is obvious they are at a low level which will have no bearing on the overall telephone circuit noise. Readings with 20/f weighting cannot be made accurately below 0dBrn. 20/f values should be calculated from recorded results of FLAT readings for 20/f weighted results between 0 and -13.5 dB.

4.5.3 The calculations described in Paragraphs 4.2, 4.3 and 4.4 are completed and the results entered on the form. All data is now available for analysis.

5. ANALYSIS

5.1 The results from measurements in the NMS mode in column (10) of Figure 12 shows an overall earth return current of about 4.2 amperes. This indicates there is little likelihood of a fundamental frequency problem (excessive longitudinal 60 Hertz voltage in the telephone system). Generally when the overall earth return current approaches or exceeds 20 amperes there is a possibility of a fundamental frequency voltage problem. The IT (TIF weighted amperes) value in column (5) is 1189 indicating that there is a



CONVERSION CURVE
TIF WEIGHTED dB TO
NUMERICAL TIF
FIGURE 11

possibility that the earth return current of one or more harmonic frequencies may be high enough to induce noise in a well balanced telephone circuit.

5.1.1 It is difficult to establish the precise I·T value which will indicate a noise problem exists. The overall I·T provides a broad indication of the potential interference from a power line. Normally the I·T is not measured unless a noise problem exists and the telephone company has eliminated all potential problem areas in its system. There are situations as discussed in Paragraph 1.1 where these measurements might be completed before a problem is known to exist. As a general rule when the I·T exceeds 1000 a harmonic analysis of the earth return current should be completed.

5.1.2 The I·T values for each harmonic frequency in column (5) of the example are acceptable except for 540 Hertz which is 1000. This indicates there is a potential for telephone system noise at this frequency. As a general rule if the I·T at any individual frequency exceeds 500 there is a possibility of a noise problem in parallel telephone circuits. This does not however guarantee a noise problem cannot occur when the I·T is less than 500 but that there is a lower probability of one occurring. There are other variable contributing factors such as the length of exposure, separation between the telephone and power lines, etc. (See TE&CM Section 452, Paragraph 5).

5.2 The unweighted harmonic frequency earth return current values in column (10) show there may be significant current at four frequencies. They are 180, 300, 420, and 540 Hertz with currents of 0.7, 0.6, 0.6 and 0.7 amperes respectively. There is little chance of 180 or 300 Hertz contribution to the noise problem due to the low I·T. There is a possibility that the 420 Hertz component might be contributing to the telephone system noise if there is a long exposure. The 540 Hertz component appears to be the principal contributor in this case. When long exposures are involved 540 Hertz earth return currents of 0.1 ampere should not be disregarded as insignificant. A substantial longitudinal voltage can be induced in the telephone system which should not be considered a power system problem since the I·T would only be 132. (See TE&CM Section 452, Paragraph 5).

5.3 The numerical TIF values from column (12) show good correlation to those from Table III of TE&CM Section 452.

Frequency	Column (12)	Table III
180 Hertz	29	30
300 Hertz	224	225
360 Hertz	380	400
420 Hertz	624	650
480 Hertz	955	950
540 Hertz	1349	1329

5.4 The differences between numerical TIF and Table 3 values are to be expected as are those between overall NMS measurements and power summations. They occur since it is not possible to complete all measurements at the same instant. During the time required to complete the measurements

POWER SYSTEM CURRENT WAVE FORM ANALYSIS

Central Office ALPHA

Power Company BETA ELECTRIC Sheet No. 1

Primary Voltage 7.62 kV. 3-Phase Date 6/1/75

Test Location Adjacent to Pedestal A1-5 A1 Route Time 2:30 P.M

Test Condition Clear and Hot Tester Doc

☐ 100 foot probe wire ______ ☒ Exploring coil type: CCS-105

Power Line Height (Average) 31 Feet (1); Correction Factor 23.0 dB (2)

FREQ. Hz.	Harmonic	TIF Weighted (Weighing Switch in C-MSG.)			Unweighted (Weighing Switch in 50 KHZ-FLAT or 20/F)					TIF Contribution	
		Reading dB (3)	(2)+(3) $I_f \cdot W_f$ dBA (4)	$I_f \cdot W_f$ wtd. amps (5)	Flat Reading dB (6)	20/f Factor (7)	(6)+(7) or 20f Reading (8)	(8)+(2) -40 dB =(I_f)dBA (9)	I_f amps (10)	(3)-(8) +40 dB =(T_f) dB (11)	T_f (12)
60	1	-			38.0	-9.5	28.5	11.5	3.8		
120	2	-			8.0	-15.6	-7.6	-24.6	0.1		
180	3	3.0	26.0	20	33.0	-19.1	13.9	-3.1	0.7	29.1	29
240	4	-			-	-21.6	-				
300	5	19.0	42.0	126	35.5	-23.5	12.0	-5.0	0.6	47.0	224
360	6	-2.0	21.0	11	11.5	-25.1	-13.6	-30.6	-	51.6	380
420	7	28.0	51.0	355	38.5	-26.4	12.1	-4.9	0.6	55.9	624
480	8	1.0	24.0	16	9.0	-27.6	-18.6	-35.6	-	59.6	955
540	9	37.0	60.0	1000	43.0	-28.6	14.4	-2.6	0.7	62.6	1349
600	10	1.0	24.0	16	5.5	-29.5					
660	11	7.0	30.0	32	10.0	-30.4					
720	12	6.0	29.0	28	8.5	-31.1					
780	13	16.0	39.0	89	17.5	-31.8					
840	14	1.0	24.0	16	2.0	-32.5					
900	15	14.0	37.0	71	14.0	-33.1					
960	16	-			-	-33.6					
1020	17	-1.0	22.0	13	-1.0	-34.2					
1140	19	20.0	43.0	141	20.0	-35.1					
1260	21	-1.0	22.0	13	-1.0	-36.0					
1380	23	11.0	34.0	50	12.0	-36.8					
1500	25	9.0	32.0	40	10.0	-37.5					
1620	27	4.0	27.0	22	5.0	-38.2					
1740	29	6.0	29.0	28	7.0	-38.8					
1860	31	2.0	25.0	18	3.0	-39.4					
1980	33					-40.0					
2100	35					-40.4					
2220	37					-40.9					
2340	39					-41.4					
2460	41					-41.8					
2580	43					-42.2					
2700	45					-42.6					
2820	47					-43.0					
2940	49					-43.3					
3060	51					-43.7					
3180	53					-44.0					
			(I·T)dB	I·T				(I) dBA	I	(TIF)dB	TIF
PWR SUM		37.7	60.7	1088	45.9		29.0	12.0	4.0	48.7	272
NMS		38.5	61.5	1189	46.5		28.5	12.5	4.2	49.0	282

		Height of Power Line Above Probe Wire or Coil								
		20'	25'	30'	35'	40'	45'	50'	55'	60'
Height Correction Factor dB	100' Probe Wire	0.5	1.1	1.6	2.1	2.5	2.9	3.3	3.6	3.9
	Exploring Coil	19.5	21.5	23.0	24.4	25.5	26.6	27.5	28.3	29.1

FIGURE 12

EXAMPLE – INITIAL MEASUREMENTS – EARTH RETURN CURRENT

there will be variations in the power system loads producing these minor differences.

5.5 The 540 Hertz component is the predominant harmonic in the majority of noise investigations. Power line resonance is often a factor which can be further aggrevated by capacitor bank installations. A capacitor bank located on the field side of the location of the measurements shown in the example (Figure 12) will be assumed. This bank can be suspected of contributing to the noise problem.

5.6 Additional measurements of the harmonic frequency earth return current should be made at locations along the power line both directions from the capacitor bank. It will be assumed that the recorded results of these measurements at a location on the field side of the capacitor bank show an I·T of 442 at 540 Hertz and an earth return current of 0.3 amperes. This provides further confirmation that the capacitor bank is a major contributor to the noise problem.

5.7 At this point the power company should be contacted. Enough information has been accumulated to determine that a condition in the power line operation is apparently the principal source of the telephone system noise. The information is in units (I·T and I) which will assist a power company engineer in making decisions regarding possible actions to relieve the problem. Even when the telephone engineer or technical has made some assumptions relative to the noise contribution from various power system components the final determination should be left to the power company.

5.7.1 Present all of the earth return data to the power company together with additional information showing that telephone shields are continuous and the telephone circuits have excellent balance. Negotiate an agreement with the power company to temporarily remove the ground connection from the capacitor bank. During the period the ground connection is removed the telephone company repeats the original measurements near the capacitor bank.

5.7.2 It will be assumed for the example that the recorded results of power system earth return current measurements with the capacitor bank ground connection removed are those shown in Figure 13. The I·T at 540 Hertz has been reduced from 1000 to 22. The earth return current could not be measured although calculations determined it was now about 0.016 ampere. The I·T of the 420 Hertz component has been reduced from 355 to 335 and the earth return current from 0.6 to 0.5. Noise measurements should be made at the subscriber location with the capacitor bank ground removed. It will be assumed that the 420 Hertz component is not a significant factor in the overall noise.

5.7.3 Recorded results of noise measurements at the subscriber residence are: Power Influence, 89.2 dBrnc and Circuit Noise, 12.5 dBrnc giving a balance of 76.7 dB. Even though the power influence is still in the marginal range there has been a marked reduction from the results of the original measurements made at the same location with the capacitor bank connected to ground. Original measurements were: Power Influence, 105.5 dBrnc and Circuit Noise, 28.0 dBrnc giving a balance of 77.5 dB. This confirms the capacitor bank was the principal contributor to the noise problem.

POWER SYSTEM CURRENT WAVE FORM ANALYSIS

Central Office ALPHA

Power Company BETA ELECTRIC Sheet No. 2

Primary Voltage 7.62 kV. 3-Phase Date 6/2/75

Test Location · Adjacent to Pedestal A1-5 A1 Route Time 10:30 am

Test Condition Clear and Hot Tester Doc

☐ 100 foot probe wire ______ ☒ Exploring coil type: CCS·105

Power Line Height (Average) 31 Feet (1); Correction Factor 23.0 dB (2)

FREQ. Hz.	Harmonic	TIF Weighted (Weighing Switch in C-MSG.) Reading dB (3)	(2)+(3) $I_f \cdot W_f$ dBA (4)	$I_f \cdot W_f$ wtd. amps (5)	Unweighted (Weighing Switch in 50 KHZ-FLAT or 20/F) Flat Reading dB (6)	20/f Factor (7)	(6)+(7) or 20f Reading (8)	(8)÷(2) −40 dB =(I_f) dBA (9)	I_f amps (10)	TIF Contribution (3)−(8) +40 dB =(T_f) dB (11)	T_f (12)
60	1	-			37.0	-9.5	27.5	10.5	3.3		
120	2	-			7.0	-15.6	-8.6	-25.6	0.1		
180	3	-1.0	22.0	13.0	27.5	-19.1	8.4	-8.6	0.4	30.6	34
240	4	-			-5.0	-21.6	-26.6				
300	5	20.0	43.0	141	37.5	-23.5	14.0	-3.0	0.7	46.0	200
360	6	-3.0	20.0	10	10.0	-25.1	-15.1				
420	7	27.5	50.5	335	38.0	-26.4	11.6	-5.4	0.5	55.9	624
480	8	-1.0	22.0	13	7.0	-27.6					
540	9	4.0	27.0	22	10.0	-28.6					
600	10	-			-2.0	-29.5					
660	11	15.0	38.0	79	17.5	-30.4					
720	12	-			-5.0	-31.1					
780	13	17.4	40.4	105	18.2	-31.8					
840	14	-			-	-32.5					
900	15	12.5	35.5	60	13.0	-33.1					
960	16	-			-	-33.6					
1020	17	20.0	43.0	141	20.0	-34.2					
1140	19	19.0	42.0	126	19.0	-35.1					
1260	21	16.0	39.0	89	16.5	-36.0					
1380	23	15.0	38.0	78	15.5	-36.8					
1500	25	7.3	30.3	33	8.0	-37.5					
1620	27	-1.0	22.0	13	0	-38.2					
1740	29	8.8	31.8	39	9.8	-38.8					
1860	31	2.0	24.0	16	2.7	-39.4					
1980	33					-40.0					
2100	35					-40.4					
2220	37					-40.4					
2340	39					-40.9					
2460	41					-41.4					
2580	43					-41.8					
2700	45					-42.2					
2820	47					-42.6					
2940	49					-43.0					
3060	51					-43.3					
3180	53					-43.7					
						-44.0					
			(I·T)dB	I·T				(I) dBA	I	(TIF)dB	TIF
PWR SUM		30.2	53.2	455	42.5		27.8	10.8	3.4	42.4	132
NMS		29.5	52.5	422	41.5		27.2	10.2	3.2	42.3	130

Height Correction Factor dB		Height of Power Line Above Probe Wire or Coil 20'	25'	30'	35'	40'	45'	50'	55'	60'
	100' Probe Wire	0.5	1.1	1.6	2.1	2.5	2.9	3.3	3.6	3.9
	Exploring Coil	19.5	21.5	23.0	24.4	25.5	26.6	27.5	28.3	29.1

FIGURE 13

EXAMPLE – SECOND MEASUREMENT – EARTH RETURN CURRENT

5.7.4 Arrange another meeting with the power company representatives and present the new recorded data. Negotiate with the power company to obtain relief from the effects of the capacitor bank. While the final decision as to corrective action rests with the power company the telephone company representatives need to be aware of the options available. The effects of power system resonance which may be aggravated by capacitor banks can be reduced in several ways.

5.7.4.1 The capacitor bank can be relocated to a point closer to the sub-station. This reduces the cable length that is exposed to the high harmonic frequency earth return current. There are sometimes situations where the capacitor bank can be removed completely.

5.7.4.2 A harmonic shunt installed in the ground lead of the capacitor bank can be tuned to supress the interference of voice band harmonic frequencies. This technique has been quite effective in the field.

5.7.4.3 Some power companies will remove the ground connection permanently from the capacitor bank. While this technique can effectively reduce interference, there are some potential safety hazards involved. It is not, therefore, a recommended procedure.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1980—340-938/REA-4267